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ABSTRACT

This document presents discussions of research findings on different aspects of baseball. Discussions of fundamentals and specific skills are presented; selected references follow each chapter. In the chapter on batting the importance of body mechanics, grip, and body rotation to the need for power is discussed. Pitching considerations that are treated include body mechanics, common faults, stride, and speed of pitched balls. Chapter three, concerned with baseball for young Americans, concludes that competition in organized baseball programs is not detrimental to the youngster, with the possible exception of injury to the pitcher's arm. Chapter four discusses baseball strategy, concluding that presentations of research on baseball, such as this, historically are not well heeded by baseball organizers and administrators. Chapters five and six give baseball potpourri, that is, brief discussions of other aspects of the game, such as throwing, reaction time and movement, physical demands of the game, antitrust laws, and the ball. (JA)

WHAT RESEARCH TELLS THE COACH ABOUT

BASEBALL

Prepared by
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WHAT RESEARCH TELLS THE COACH SERIES

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FOREWORD

This is the fourth in a series of booklets entitled "What Research Tells the Coach" about a specific sport or activity. These booklets are designed to make pertinent research findings and their practical applications available to coaches, as well as to point out areas in which additional research is needed before definite conclusions can be drawn.

Guy G. Reiff, the author of this volume, is a prominent statistician and investigator in the field of physical education. Dr. Reiff has had a lifetime interest in this great sport, and was also a fine player and coach.

We believe this to be the first book on baseball of this kind, and also one of the most outstanding yet published on the game. An eminent researcher and a baseball coach who reviewed the manuscript consider it an important project. Wherever feasible, their suggestions were incorporated into the final version.

The book attempts to inform the coach of what is - and what is not - known about most of the various aspects of baseball. The author interprets the research findings, and also lists additional readings on each subject. Since only a minimal amount of technical language has been used, it is hoped that the modern baseball coach will be familiar with the terms used in the body of the material.

It is believed that this fine publication may open new avenues and widen old ones. It offers some new ideas to the perceptive and receptive baseball coach, and we are pleased to have been a part of this most worthy undertaking.

John M. Cooper

PREFACE

It is appropriate to first make grateful acknowledgement to the reviewers who gave unselfishly of their time, and whose comments and suggestions have added immeasurably to this booklet. Thanks are also extended to the American Association for Health, Physical Education, and Recreation for support and encouragement, and for presenting the opportunity to contribute, in a small way, something more to a sport to which I owe so much.

It seems like a good idea in any field to attempt, from time to time, to summarize the present state of the art. This review was tailored to present such a summary, and, hopefully, to appeal to baseball fans and other interested lay people as well as physical educators and coaches. Thus the use of as little technical language as possible, and the emphasis on a synthesis and interpretation of the material rather than a more rigorous, scholarly review. Some inductive leaps have been made, mostly because it is fun to do so, and also because one of the objectives of a publication of this type is to provoke some discussion and differences in viewpoint. And, finally, I have attempted to heed some of my old parental admonishments to wit, "be brief," "talk plain," "say what you think." I have tried to do all three.

Guy G. Reiff

1. BATTING

Can he hit? Baseball coaches from little league to major league baseball invariably pose this question when assessing a baseball player's potential. Coaches generally assume that a player can be taught to hit, whereas one can do little to develop such inborn talents as running speed or a strong throwing arm. The art of hitting a baseball has been largely derived from tobacco-stained assumptions and hand-me-down lore. This practice has germinated a mystique related to batting performance and strategy that over the years has become piously accepted by both performers and fans. This does not mean that *all* of the assumptions and folklore which surround the sport are wrong. Indeed, there are many instances in sports research where objectively derived data have basically agreed with many of the assumptions; conversely many have also been disproved.

What does the research literature tell us about the art of hitting a baseball? Specifically (a) what body mechanics can be applied to improve a hitter? (b) what muscles can be strengthened to improve power? (c) what is the relationship between hitting and vision? and, (d) the $64 question, what makes one hitter better than another? Granted, the measurement of many of the factors involved in these problems is formidable, yet many have been researched. Let us now review the state of the art.

Body Mechanics

The body mechanics required to hit a baseball with power have been firmly and scientifically established. Naturally there are various preparatory movements and positions prior to starting the swing, but the basic sequence of body movements is: (a) short stride, (b) rotation of the body at the hips and shoulders, (c) rapid extension of the forearms, and (d) rapid uncocking of the wrists.

Breen (3) has presented an excellent summary of the hitting styles of six great hitters – Ernie Banks, Ted Williams, Stan Musial, Henry Aaron, Willie Mays, and Mickey Mantle. Careful cinematographical analysis disclosed that each had a unique hitting style, yet each had five basic mechanical attributes in common. These were:

1. The center of gravity of the body followed a fairly level plane throughout the swing.
2. The head was adjusted from pitch to pitch to get the best and longest possible look at the flight of the ball.
3. The leading forearm tended to straighten immediately at the beginning of the swing, thus resulting in a greater bat speed.
4. The length of the stride was essentially the same on all pitches.
5. After hitting the ball, the upper body position was in the same direction as the flight of the ball, thus transferring the weight to the front foot.

Each of the body movements must naturally come with great speed and in correct sequence, resulting in a "summation of forces" and maximum power. Let us examine each of these movements with the intention of establishing some guidelines for optimum performance.

Preparatory Position and Movements

Grip. There is no relationship between batting or slugging averages and preparatory actions such as distance of hands away from the body, distance the bat is moved in a counter direction to the forward swing, angle of wrist cock, or stance. Most studies agree that there are wide variations in all these factors. Race (22) sums it up best by concluding that, "assuming that these preparatory movements are habitual . . . there seems to be little justification for emphasis on these actions beyond preparedness, alertness, free movement, and relaxation or comfort."

The position of the hands on the bat should be firm to avoid recoil and loss of power, and adjusted to strength of the grip, wrists, and arms, and the weight of the bat. Players with weak wrists can compensate by either choking the bat, or by spreading the hands. This will result in a shorter lever and will enable the weak batter to make a controlled and effective swing. Carroll (6) studied five different grips and concluded that maximum velocity was attained when the middle knuckles of both hands were aligned. This grip also allowed a greater range of motion in the wrist joint than other grips studied.

Stride. The justification for the stride is to increase the body momentum and thus, assuming the ball is hit, increase the force of the hit. Since the rotary action of the hips is somewhat dependent on the stride, a short stride is recommended. Bunn (4) emphasized that striding too far locks the hip and causes the body to fall away from the plate, thus losing power. He also pointed out that Lou Gehrig, despite his hitting prowess, had this bad habit. Bunn's example of Lou Gehrig is a timely one here, since Race, in an exhaustive cinematographical analysis of seventeen Class A Eastern League hitters reported no relationship between either length or velocity of stride and batting or slugging average. Since speed and length of stride has been a controversial topic, these data are presented in Table 1 to enable the reader to examine this variability in detail. Note that these players were proficient, effective batters (three qualified for individual batting championships, three rated among the top ten in RBI's, three were in the top ten in home runs, three in the top ten in total bases, and three in top ten in total base hits).

The start of the stride (assuming ball speeds between 55 and 89 miles per hour) should be geared to the release of the ball by the pitcher. Hubbard (13) found this pattern in professional batters, and also reported that the start of the swing was closely related to the finish of the stride, tending to occur about 0.04 seconds after the stride foot was firmly planted.

Body Rotation. The basic pattern of the body turn has been firmly established. The rotary motion is initiated by a strong hip rotation: the hips either rotate forward while the shoulders remain the same, or the shoulders and bat first rotate backward slightly. A slight backward rotation of the shoulders and bat is recommended because it: (a) overcomes the inertia of the bat (thus placing the bat in motion), (b) increases the arc of the swing and, (c) stretches the shoulder and hip muscles, thus generating more force. Race reported average velocities of hip rotation from 83.9 inches per second at 80° to 106.7 inches per second at 100° – that is, as the degrees of rotation increase, so does the speed. Note also in Table 1 that he reported a mean stride velocity of 35.2 inches per second, indicating the relative slowness of the stride when compared with the hip rotation. There is general agreement that this dramatic rotation of the hips is one of the most effective bodily movements employed by successful hitters.

The lean, or incline, of the body and the position of the head are also interesting. Race reported a mean body lean of 88° in the stance. This figure did not change significantly throughout the swing. Almost all (14 of 17) hitters leaned slightly (88°) toward the catcher, laterally, during the stance. He concluded that the angle of body lean represented a major factor in the total centripetal force (the force directed toward the center of rotation). Other evidence shows that the inclination of the trunk *toward* the plate remains relatively constant throughout the swing. There is also general agreement that the position of the head remains *relatively* constant throughout the swing, although Race reported an averag decrease in head level of 6.5 percent of the player's filmed height during the swing.

TABLE 1. RELATIONSHIP OF STRIDE TO BATTING AND SLUGGING AVERAGES[a]

Player	Stride (inches)	Stride Velocity (in./sec)	1959 Averages Batting	1959 Averages Slugging
G. Valentin	5.2	23.4	.311	.391
A. Asaro	5.3	18.8	.346	.488
W. Spiers	5.8	58.2	.265	.388
D. Davis	6.0	14.3	.283	.401
D. Bennetch	6.2	26.0	.284	.465
J. Davis	6.3	19.7	.254	.412
R. Farley	8.1	27.1	.313	.457
D. Mann	8.4	29.8	.318	.458
L. Reveira	10.7	26.7	.380	.588
L. Stubing	10.7	29.8	.300	.454
T. Haller	10.9	43.6	.276	.385
M. Mota	11.7	25.4	.314	.449
C. Horn	11.7	48.5	.259	.395
W. Carr	11.9	29.8	.300	.452
L. Thomas	13.3	47.5	.304	.500
W. Kern	17.5	48.6	.316	.532
M. Alou	31.0	8' 7	.288	.446
Mean	10.6	35.2	.297	.446

[a]From Race (22) Table rearranged so players are listed by stride length.

Forearm and Wrist Action. Race also reported objective data disclosing that the forearm and wrists travel faster than other body parts during the swing. The mean velocities from 80° to 100° ranged from 169.6 inches per second to 215.8 inches per second. When compared with the rotary hip and stride velocities it is important to note the much higher velocities of the forearms and wrists. Thus, in accordance with Bunn, objective evidence is presented that each successive member of the body should move faster than its predecessor for optimum speed to be obtained. The importance to the swing of quick and powerful wrist action has been firmly established by the research literature.

Muscle Strengthening for Power

Research relating to the improvement of batting performance by the strengthening of selected muscle groups is scarce. Generally, the research discloses that the right hand is dominant in imparting velocity to the bat (the left hand contributes little), and that there is a slight relationship between bat velocity and grip strength. There also appears to be some evidence that relatively short weight training programs (six weeks) accomplish little in improving batting skill or power, at least with varsity-caliber players(10).

A carefully done electromyographic study of the batting swing by Kitzman (14) traced six muscle groups. He studied the right and left pectoralis major muscles (clavicular heads), the right and left triceps brachii muscles (lateral and long heads), and the right and left latissimus dorsi muscles. By strengthening the left triceps brachii muscles (long heads) it was concluded that right-handed batters can increase the force that they can transfer to the bat. This study was interesting because two professional baseball players and two college students who did not play baseball were studied.

A study by Hooks (11), although not expressly designed to investigate the possibility of increasing hitting power, should be mentioned here. He reported that upper arm girth and left shoulder flexion had the highest relationship to batting success of the nineteen structural and strength variables measured.

Hitting and Vision

Visual tracking of the baseball, and its effect on the swing, has created some controversy. Investigators generally agree that the ball is not tracked visually right up to bat contact, and that the stride is geared to the release of the ball by the pitcher. Just when the swing is begun, however, has been debated. This argument is related, naturally, to reaction and movement time and the distance of the ball from the plate. Slater-Hammel (29) concluded that the batter must decide where the ball will be before it reaches the midpoint of its flight for a starting reaction, and for choice movement he must decide at a time when the ball is 35-48 feet from the plate. Slater-Hammel recommended that a batter make his reaction to a pitch a starting--rather than a movement--reaction, thus enabling the batter to observe the ball longer and presumably achieve a higher batting skill; he also concluded that reported data indicate that fast balls can range in speed from 0.43 to 0.58 seconds from mound to plate, and that a batter cannot successfully delay his swing until the last few feet.

Hubbard and Seng (13), in an exhaustive cinematographic analysis, photographed eye movements of college and professional players during batting practice. They concluded that it was primarily pursuit movements of the eyes which seemed to track the ball; that is, the head was essentially fixated and the eyes moved. Convergence and some compensatory movements were found, but there was no evidence of saccadic jerking. Professional batters at ball speeds ranging from 55 to 89 miles per hour coordinated the start of the stride with the release of the pitch; the *duration* of the stride and the *start* of the swing were geared to ball speed--starting later for slower pitches. The start of the swing was closely related to the finish of the step and tended to occur about 0.04 seconds after the striding foot was firmly planted. Irrespective of ball speed, the swing appeared to have relatively uniform duration.

These researchers reported that the ball was tracked to within 8 to 15 feet of the plate, and that reports of ability to track to contact were based on visual and perceptive illusions (assuming a fast pitch). The distance the ball was tracked before the swing occurred accounted for the difference in explanation of the timing of the swing between Hubbard and Slater-Hammel. Hubbard claimed that batting is essentially a perceptual and motor problem, and that "batting reaction-time" is primarily an academic problem with little or no demonstrable analogy to actual batting because of the confounding variables of differentiating speed and direction.

The simple act of eye blinking has been reported to ". . . account for errors in human performance ranging . . . from misread scientific instruments to missed tennis balls" (24). Slater-Hammel (24) subsequently pointed out that a pitched ball could cover a distance of 9 feet during an average blink blackout, thus the ball could not be seen over a range of 6 to 14 feet of its flight. Both Slater-Hammel and Norris (20) investigated the effect of eye blinking on batting performance. Both reported that the frequency of blinking was markedly decreased during reaction time responses, and that blinking had little effect on reaction time measures.

A review of studies which related results of vision tests with batting and slugging averages generally disclosed no significant relationships between the two. Mauro (an ex-professional baseball player) has been the single exception (17). Two optometrists administered Opthalmoscope, Snellen, Arc-Perimeter, Retinoscope-Phoropter, Keystone Telebinocular, and Tachistoscope tests to a sample of college baseball players representing two universities. Correlations ranged from 0.50 to 0.77 with the Retinoscopic-Phoropter and the Tachistoscope test and batting averages. All other correlations were negligible. Mauro also reported a 0.73 correlation between batting averages and the Keystone Telebinocular test on players from one university, but negligible correlation on this test and batting averages with players of the other. This single inverse relationship between a visual test and batting averages should obviously be interpreted with some caution.

Winograd (34) reported data, however, which showed definite differences in visual acuity between college varsity baseball players and rejected candidates in directed timing, far point lateral imbalance, and simultaneous vision. He also provided other explanations, summarizing the lack of significant relationships between tests of vision and batting, by suggesting that "muscular strength, correct form, and proper mental attitude are probably developed to a greater degree in compensation for visual inferiority."

Research findings relative to the effect of eye dominance on batting seem inconclusive. The popular argument of the eye dominance theory generally claims that a batter with crossed lateral dominance (left-eyed and right-handed and vice versa) has a distinct advantage over the unilateral batter (right-eyed and right-handed and vice versa). This · due to the position of the batter's dominant eye in relation t te., and also to the fact that, in a unilateral right-handed batter, the dominant eye is partially obstructed by the batter's nose. The crossed lateral batter is not supposed to have this problem. There is some agreement with this theory, college players with crossed laterals have been reported to be better in batting average, slugging average, and in obtaining bases on balls (9).

Adams (1), however, studying 32 varsity baseball players from three colleges, concluded that the crossed lateral batter performed no better than the unilateral. He found that the unilaterals reached base significantly more often, and also had a higher batting average. Only in the missed swing category did the crossed laterals have a slightly better record. Adams also suggested that those unilaterals who used an open stance significantly outperformed those unilaterals who used a closed stance. He suggested that "the superior batting performances of the open stance unilaterals certainly proves the old saying that 'two eyes are better than one'."

Summary

Now that the research findings on batting have been reviewed, one must pose the question, "What makes one hitter better than another?" This, as emphasized earlier, is truly the $64 question. What does the research literature tell us relative to this question?

Perhaps the basic formula M = mv (momentum equals mass times velocity), would serve as a capsulized synthesis for the hitter.[1] Since the variable here is the weight of the bat (assuming the hitter's weight is optimum for his position and stature), one might recommend, "Select the heaviest bat that you can swing the fastest and utilize these four basic fundamentals:

1. Use a dramatic, fast, and powerful rotary action of the hips.
2. Straighten the leading forearm immediately at the beginning of the swing and utilize a quick and powerful wrist action.
3. Use a fairly stable head action, coupled with a tracking action of the eyes.
4. Keep the length of stride constant on all pitches."

One could also, naturally, mention the other commonly voiced axioms of good hitting, i.e., short stride, fast reaction time, etc. Yet it should be re-emphasized (Table 1 and other observations) that many excellent hitters violate some of these tenets, and researchers still appear to disagree somewhat when

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[1] It is important to observe, however, that the batter is often more concerned with making contact with the ball in such a way that the ball goes to a specific place than with "knocking it out of the park." Hence, *power* at impact is not always his goal, instead, his goal is placement.

attempting to quantify good hitting rigorously in terms of reaction times or the ability to differentiate the speed and direction of pitches in split seconds. The multivariate nature of these measurements, both psychological and physiological, and the costliness of the research, perhaps have posed insurmountable obstacles to the resolving of this question. Certainly one would be forced to admit that, besides the physiological and kinesiological elements of good hitting, a great many psychological variables must be considered. The desire to practice incessantly, the mental discipline required to "zero-in" on the task at hand, as well as the whole psychological make-up, determination, and confidence of the individual player, still defy measurement and quantification.

One often repeated and basic principle verified by authors quoted in this review is that "when the ball is contacted (or released), velocity should be at a maximum and acceleration should be at a minimum, preferably zero." The critical factor at the instant of impact is the velocity of the bat. Good batters coordinate their movements in such a way that the bat has stopped accelerating (but is at maximum velocity) by the time it contacts the ball. Poor batters bring the "batting muscles" into play "late" in the swing, and, as a result, the bat is still accelerating after the impact (in which case the velocity gained is of no avail because the ball is already on its way!).

Perhaps the strongest statement that can be made about a good hitter is that, above and beyond the approximation of good body mechanics, he has an indefinable ability to get the bat on the ball with authority more often than a poorer one. He probably approximates somewhat most of the axioms of good hitting fundamentals; if he is deficient in one he may overcompensate in another. This has certainly been indicated in some of the research observations on body mechanics as well as in tests of vision. Remember that in baseball hitting, unlike other sports, the truly successful performance is universally acclaimed as a 0.300 hitter. Any student of elementary arithmetic will immediately recognize that an established, "successful" hitter fails to hit about 70 percent of the time. It is interesting to note that a truly great hitter such as Ted Williams (33) generally agrees with the principles of hitting summarized here.

This brings to mind the old question, "But how good would he have been if he had done it right?" How can one measure this? For if one's physical accomplishments are such that he can place the bat on the ball with the authority of some of the game's great hitters, yet only approximate or ignore some of the basic assumptions of sound body mechanics, what would be the value in changing technique?

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2. PITCHING

Effective pitching, if one is considering the game at all levels, has been generally conceded to be 65 to 85 percent of winning baseball. The depth and coverage of published research related to pitching, however, is not as sophisticated as the research on other aspects of the game. No doubt cost and a lack of valid and reliable measuring instruments applicable to the complex physical, psychological, and emotional variables involved has hampered the publication of more research. The research literature germane to the skill of pitching a baseball can be broadly classified into three areas: (a) analysis of body movements involved in the throw, (b) improvement of technique and, (c) velocities and spin of various types of pitches.

Body Mechanics

The mechanics of throwing a baseball have been well established (1, 2, 9, 15, 18). Pitching, however, is even more specialized because maximum speed is not always desired, nor, obviously, is maximum distance. The ability to change the speeds of various pitches and to control the pitch are at least equally as important. Since, however, as in many other types of throws, the primary objective is the generation of force and velocity and the impartation of it to the ball, it is important to review how this is accomplished. In the discussion that follows only the overhand throw will be used as an example.

A throw involves both a rotary and a linear motion. The rotary action is accomplished by turning the hips and shoulders, thus enabling the pitcher to "wind-up" the back and shoulder muscles and to greatly increase the arc through which his throwing arm travels. The linear motion is triggered with a step towards the hitter, thus further increasing the body speed and literally pulling the hips, shoulders, back, and arm into the throw. It is also important to note that, opposed to other types of throws, the pitcher must begin with one foot astride a pitching rubber. This restriction obviously precludes additional preparatory steps, or the short run used in many other types of throws. Additional generation of body momentum is accomplished through a wind-up.

The wind-up is started with a slight rocking action of the body and a sidewise pivot of the foot on the pitching rubber, thus permitting the rotation of the hips and upper torso. This action also permits the pitching arm to extend well down along the side of the leg before the forward motion is begun--a fact frequently overlooked by many coaches. In this position the leg not on the rubber is usually bent at the knee for better balance.

The forward step, or stride, initiates the linear action, developing an integrated, fluid movement with a gradual increase in velocity as each body part is added to the action, thus pulling the arm through its arc as the hips and shoulders unwind. The striding foot hits the ground just to the left of a line from the center of the pitcher's body to the center of home plate. The forearm and wrist lead the ball until the wrists are uncocked, the ball leaving the hand just about on a vertical line through the bill of the cap as the forearm passes a vertical position. It is important to note that with accomplished performers the elbow is well ahead of the ball before uncocking the wrists.

The classic follow-through, or finishing position, is with the body square to the hitter and the hands in a fielding position. Many accomplished pitchers, however, do not finish in the classic position; the force of their follow-through requires a second step in order to finish in an excellent fielding position. A good follow-through position is extremely important, although it should be emphasized that the follow-through itself adds nothing to the flight of the ball; its primary contribution is to eliminate injury from an abrupt or jerky finish and to enable the pitcher to knock down or field a ball hit back through the box.

Common Faults

A review of the basic body mechanics unique to the pitching motion suggests some elementary violations of these fundamentals that, especially in young and inexperienced pitchers, could adversely affect their development and effectiveness. These are:

1. Throwing or pivoting with the foot on the top of the pitching rubber, thus losing body stability and speed of forward movement derived from pushing off the front of the rubber (Newton's third law, "for every action there is an equal and an opposite reaction").
2. Incomplete extension of the throwing arm in the wind-up. This will result in less force imparted to the ball because of the smaller arc and less distance through which the arm must move to develop velocity.

3. Stepping across the body with the striding foot, resulting in a closed rather than an open position before release. This fault results in a restricted hip and shoulder turn during the delivery, and interferes with the summation of forces derived from the proper sequence of the body parts, thus losing ball speed, affecting control, and impairing a proper follow-through position. This fault can also result in injury to the throwing arm, or excessive soreness or stiffness a day or so after pitching.
4. Landing on the heel rather than on the forward part of the striding foot. This fault can interfere with the proper sequence of the body parts immediately before delivery, and seriously affect the development of ball control. It is also possible that some arm soreness may develop.

One can conclude empirically that the execution of the proper body mechanics is basic to the development of the complex skill of baseball pitching. Naturally, the proper integration of body movements is not independent of other factors such as control, and the ability to throw the ball "hard" and "alive" as it approaches the strike zone. There have been many pitchers who could throw with exceedingly high velocity, yet who lacked control, thus more frequently "grooving" the ball for extra base hits or, worse, walking an exceedingly high number of opposing batsmen. These pitchers have never been consistent winners against good competition. It seems natural, then, to provoke questions such as: Can throwing velocity be improved through training? How can control be improved? Alas, research evidence establishing any body of knowledge from which to formulate conclusions is scarce.

Improving Performance

Electromyographic work (11) has indicated that during the throw and in terms of check action, an antagonistic function is performed by the deltoid, middle, and posterior head; the teres major; latissimus dorsi; and biceps brachii, long head. During the throw, and in terms of the follow-through, an agonistic function is performed by the trapezius, upper part; the deltoid, anterior head; teres major; latissimus dorsi; triceps brachii, medial head; and the serratus anterior, lower part. Conversely, an antagonistic function is performed by the deltoid, middle, and posterior heads; and biceps brachii, long head.

Attempts to improve the velocity of the throw through progressive resistance exercises have been spotty and generally inconclusive (17, 26, 27). Most of these studies examined the effect on both accuracy and velocity of training the throwing arm through isotonic and isometric exercises, and included various combinations of unrelated exercise and throwing, related exercise and throwing, etc. Generally speaking, it has not been conclusively shown that any of these exercise combinations will increase either speed or accuracy.

There have been a few attempts to investigate whether there is any definite pattern of joint movement which might enable one pitcher to throw with greater velocity than another, and, also, the effect of an overload warm-up on the velocity and accuracy of throwing (11, 12). Cinematographical analysis of the overhand baseball throw indicates that pitchers who have the greatest forward flexion at the hip joint at the time of release record the highest velocities. The release of the ball seems to occur when the spinal rotation is between 105° and 115° forward from the line drawn directly from the subject to the target. Studies made on the ability to throw for distance (even through not directly related to pitching), seem to indicate that distance throwing demonstrates some association to age and weight, grip, wrist, and shoulder medial rotation strength, and with the length of the hand, lower arm, and upper arm as a proportion of total arm length.

There is some evidence which indicates that an overload warm-up may improve both velocity and accuracy (24), but further corroborative evidence is needed. This research indicates that warming up with an 11-ounce ball seems to improve the velocity of throwing. Accuracy following the warm-up was altered somewhat for the first few throws, but improved rapidly. Further investigation was indicated, however, as the subjects made only ten throws each. This type of evidence identifies a provocative area of potential research.

Stride

There have been several inquiries into the effect of the pitcher's stride, position on the rubber, and point of aim on both speed and control of a pitched ball (4, 13). When wildness is defined as the type of inaccuracy in which the pitcher is consistently pitching out of the strike zone in a definable pattern rather than being inconsistently wild (one high, one low, etc.) many coaches have advocated changing position or stride on the pitching rubber. The available research relative to this theory suggests that neither changing the length of stride, changing the position of the pivot foot, or both, will necessarily correct this type of wildness. Other findings are reported which indicate that changing the landing position of the left foot (defined as either 6, 12, or 18 inches to the left of a line from the center of the pitching rubber to the center of home plate) does not improve either accuracy or speed. There is also some evidence which indicates that instructing the pitcher to throw at the center of the plate rather than at the corners will not result in any identifiable improvement in control. Proponents of the "center-of-the-plate" theory hypothesize that a good fastball will "move" or be "live" enough so that it will not usually end up where it was intended.

Velocity, Spin, and Trajectory

The velocity, spin, and trajectory of pitched balls historically have been lively subjects for "hot stove league" debate. The curve ball has probably been the center of the most controversy. Despite scientific explanations of the curvature of the ball, many baseball fans, scientists, and journalists have tried to prove or disprove its existence, or at least whether it curves as much as baseball players and sportswriters claim. Also, in recent years baseball has acquired a vast new and critical group of fans through television who have been all too willing to render opinions tainted by camera angles or electronic distortions. These discussions have been an interesting phenomenon because few, if any, sports fans have questioned the curvature of a tennis or a golf ball, for example.

The research evidence is conclusive that the curve ball does curve. Not only does a curve ball curve when thrown by a pitcher, there is a scientific explanation for it. The explanation is derived from a principle discovered some 200 years ago by a Swiss mathematician, Daniel Bernoulli, and is called the *Bernoulli effect*. Simply stated, the principle says that the static pressure of a fluid, such as air or water, goes down as the velocity goes up. One will remember from high school physics that dynamic pressure goes up with velocity and that static pressure goes down in the same proportion. As the curve ball spins toward the plate, air is carried around it by friction; thus on one side of the ball the air moves with a current of air caused by the forward motion of the ball. On the other side, however, the air moves in opposition to it. As a result the air speed on one side of the ball is greater than on the other. This results in a lower static pressure on one side than on the other; thus the ball curves toward the side having the greater air speed and the lower static pressure. Other scientists have attributed the explanation to the *Magnus effect*, named for a 19th-century German engineer who sought to explain the curvature of cannon balls.

The force acting to deflect a curve ball from a straight line is (for all intents and purposes) a *constant* force. Hence the ball is deflected from the straight line according to the formula $F = ma$ (force equals mass times acceleration). This results in an accelerated curve, i.e., for each succeeding interval of time, the *distance* that the ball is deflected during the interval is greater than it was for the preceding interval. Therefore the nearer the pitch approaches the plate the "more sharply" it moves laterally–hence, the "break."

The spin of a curve ball has been reported at from 7 to 16 complete turns over a distance of 60 feet. If one assumes that the speed of the pitch was 100 feet per second, claimed by one investigator[1] as the most effective speed for a curve ball and well within the reach of a professional pitcher's capability, the maximum speed is 1,600 revolutions per minute. Curves of 11.7 inches at 1,200

[1] Lyman J. Briggs, Director Emeritus of the National Bureau of Standards.

rpm and 17.5 inches at 1,800 rpm have been reported as the maximum curvatures attainable for a pitched ball traveling at 100 feet per second (23). Any increase in speed for these rates of spin resulted in lesser curvatures. The amount of curvature reported above applies to balls spinning about a vertical axis. Usually, however, the spin axis of a pitched ball is inclined from the vertical, thus making the curvature considerably less. Selin (19) found the following *maximum* horizontal deviations for single pitches: fast ball, 2.1 feet; curve ball, 1.2 feet; change-up, 1.5 feet; knuckle ball, 2.5 feet; and slider, 0.8 feet.

Speed of Pitched Balls

There have been several excellent studies reporting the relative speeds of pitched baseballs. These investigations have used either cinematographical techniques or electronic devices so designed that a switch activated an electric timer and a sound wave stopped it. It has been generally accepted that a fast ball travels from pitcher to home plate in approximately 0.43 to 0.58 seconds. Other types of pitches have been measured utilizing collegiate varsity pitchers, and these results are presented in Table 2. It is interesting to note that the speeds reported for the fast ball and the curve ball are in relative agreement, even though measured by different techniques. Note also that the progression naturally is headed by the fast ball, the slider next, followed by the curve ball, knuckle ball, and change-up. Also, contrary to some popular conceptions, the knuckle ball contradicts its image of being a "floater" by disclosing speeds of

TABLE 2. VELOCITIES OF VARIOUS PITCHES

Type of Pitch	Selin		Slater-Hammel	
	Range (fps)	Mean (fps)	Range (fps)	Mean (fps)
Fast ball	87.5-121	104	95-119	107.8
Curve ball	74-111	91	80-104	92
Slider	92-102	98		
Sidearm-curve	90-92	91		
Knuckle ball	75-91	84		
Change-up	62 5-90			

From Selin (19) and from Slater Hammel (20). Selin's data represent 14 pitchers from Big Ten teams and are calculated from point of release Slater-Hammel's data represent six pitchers from University of Indiana pitching staff, and are based on an estimate of 56 feet as distance ball travels (means were calculated from Slater-Hammel's data).

from 75 to 91 feet per second, and has shown ranges overlapping that of the curve ball.

Other data reported (8, 16, 18) agree closely with the speeds presented in Table 2 and further disclose that the overhand pitch is generally faster. The overhand fast ball is about 11 feet per second faster than the overhand curve ball, two feet per second faster than the sidearm fast ball, 12 feet per second faster than the sidearm curve ball, 7 feet per second faster than the underhand fast ball, and 15 feet per second faster than the underhand curve ball. Also, the velocity of a fast ball has been reported as about 18 percent greater than the palm ball.

Summary

It is obvious that we still have a long way to go in quantifying the complex mechanical and muscular aspects of pitching a baseball (6). Physiological and psychological variables are also important, but have not been researched. One example of the complexity of the psychological parameters to be explored can be found in a hypnotic analysis of a case of aggression of a baseball pitcher. This subject reacted favorably to hypnotic suggestions and was able to pitch consistently well.

Most of the research evidence presented has agreed closely with some of the theories that have been a part of the hand-me-down folk lore which has surrounded baseball for years. Several fruitful areas for further research have been identified. These areas have been pioneered by competent, inquisitive investigators. Further intense and sophisticated research is needed; it must eventually come from those within the game itself–those who have played it, seek to improve it, and who have accumulated the necessary skills and knowledge, and desire to do so.

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3. BASEBALL FOR YOUNG AMERICA

To paraphrase from a well-known play, "To play or not to play? That seems to be the question." The rapid growth and popularity of boys baseball programs, from the highly organized Little League to rather informal community recreation leagues, have provoked some vigorous arguments on the hazards of organized baseball competition for young boys. Since many baseball coaches are solicited to organize programs of this nature, or render a professional opinion on their merits, it is the purpose of this chapter to summarize the research findings germane to this issue. Most of the research has centered about the highly organized Little League and Middle League baseball programs; however, many of the issues seem applicable to competitive or organized programs in general. The basic issues most frequently researched have been: (a) Is normal growth and development affected? (b) Is there increased stress upon psychological and emotional well-being? (c) Is there a greatly increased chance of premature injury?

It will come as no surprise to the reader to learn that these programs have proliferated throughout the United States. Many of these programs have no city, state, or national playoffs (such as the Little League has), many are of an interschool nature, and a large number are under the aegis of community recreation programs. Many parents approve whole-heartedly and feel that although some boys are adversely affected by competition the majority are not (19). Teachers of players and nonplayers generally indicate that boys on teams are highly selected and possess more physical skill, receive better grades in school, and are emotionally better adjusted than boys who do not play on league teams (8, 13, 20). There is some evidence, however, which indicates that there are a minority of parents and teachers who are opposed to intensive competition, or at best might be labeled as maintaining an extremely cautious optimism (18).

Research evidence bearing on the effect of competition on psychological and emotional well-being is contradictory, and in some instances related to athletic competition in general rather than baseball in particular. The primary concern is that the youngster does not possess the psychological or emotional maturity to weather the stresses of organized and highly competitive sports programs. There is some evidence which indicates that participation in such programs is not harmful to the youngster and that, psychologically, none of the manifestations of behavioral difficulties, psychogenic disturbances, disturbances of physiological functions, or any other traditional forms of psychoneurotic reactions have been found (19, 21, 22). Children who compete exhibit many desirable personality traits, and are better adjusted than those who do not. Other findings indicate that participants seemed no more stimulated by competition in league games than by competition in physical education classes. One investigation has reported that an overwhelming percentage of physicians whose sons played Little League baseball reported no adverse emotional effects of competition (17). Another investigation has reported that Little League leadership at national and local levels is characterized by altruistic motives and a sincere desire for improvement of the Little League program (4).

Other research findings contradict these claims. One research reports no apparent difference between participants and nonparticipants in Little League, reporting that the program of Little League baseball did not show that it had appreciably affected the personality problems of participants either in a positive or a negative manner (12). There is some indication that participants scored slightly higher on personality traits, and received higher social acceptance ratings from their peers than nonparticipants. The boys who take part in the baseball program, however, may come into it somewhat better endowed in terms of desirable personality traits and retain that position during and after participation. In other words, it is suggested that the participants start at a higher level of social acceptance, and that these changes are not directly attributable to the baseball program (19). There are other findings which state that parents have reported that their sons were too excited after games to eat normally (21). Other reports indicate that intense participation can cause disturbed sleep in these young participants (5).

There appears to be no indication that participation in boys baseball programs has any adverse effect on normal growth and development. Years of participation, total games played, or length of season seem to have no retarding effect on growth and development. Research has generally supported the fact that participation in vigorous forms of physical activity has a favorable effect on the growth of bone and muscle tissue, and that, especially in boys baseball, heavy demands are not made on the cardiovascular system.

Studies of the physiological maturity of boys who participated in the 1955 and 1957 Little League World Series show that players of championship caliber are, in general, biologically advanced (14). Such an advancement is deemed a positive factor in young boys participating in competitive sports. The 1955 players were reported as having an average chronological age of 12.5 years. Only 17 percent of the boys were pubescent, 45.5 percent were postpubescent, and 37.5 percent were prepubescent, thus suggesting that the ability to play baseball is affected by the pubertal spurt in growth. All eight pitchers who started games were postpubescents, except one who was pubescent. It is interesting to note that the batting order positions definitely indicated maturity. The greatest number of postpubescents batted in the third, fourth, fifth, and sixth positions, while all boys who batted fourth were postpubescents.

There is no question that as a result of the proliferation of programs and the increased number of participants more injuries will occur. The evidence available indicates that the majority of injuries seem to be of a minor nature and are exceptionally few in view of the large number of exposures (7). Not surprisingly, a pitched, thrown, or batted ball was the primary cause of injury, with the pitched ball causing most of the injuries. When one considers the number of exposures, however, the batted ball is reported to cause a higher *incidence* of injury than the pitched ball. Since in Little League competition it has been estimated that only one of every five balls pitched is batted, it becomes obvious that the number of exposures to the batted ball is a fraction of the exposures to a pitched ball. Approximately one-half of all injuries in Little League competition were reported to be abrasions and contusions. Only one percent of the Little League players sustained fractures sprains, concussions, or dental injuries.

There is evidence that reveals injury to the joint structure of the throwing arm in Little League players who ranged in age from 9 to 14 years, with higher incidence among pitchers than nonpitchers. It is recommended that pitchers of this age pitch no more than two innings in each game and that curve balls not be thrown prior to age 15 (3).

Summary

In general, a review of the research in this area indicates that competition in organized boys baseball programs is not detrimental to the youngster, with the possible exception of injury to the pitcher's arm. However, it is important to note that the evidence is not conclusive, and that these programs should be operated under good leadership and close supervision. Excellent guidelines for the programs are available through the AAHPER (2,3). These guidelines were formulated in concert with the American Academy of Pediatrics, the American Medical Association's Committee on Medical Aspects of Sports, and the Society of State Directors of Health, Physical Education, and Recreation.

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4. BASEBALL STRATEGY

Baseball strategy has evolved from a folklore mystique passed from mouth to mouth for over a hundred years. Player after player has been schooled by those preceding him in such aspects of the game as the legerdemain of pitching strategy, the intricacies of the sacrifice bunt, and the cunning and craft required to blend the unique skills of each batter into a hitting lineup. Baseball managers and coaches have been well indoctrinated, primarily through their own playing experiences, in the art of "playing the percentages." It is a rare fan, indeed, who does not profess even a primitive knowledge of the "percentages," or who has not castigated a manager for "going against the percentages."

The ironic and paradoxical fact of the matter is that, up to several years ago, nobody knew what the percentages really were (or if they did, were keeping the facts to themselves). This fact is all the more amazing when one considers the nature and the intricacies of the game when it is compared with other sports. Baseball consists of a great number of repetitive situations; the rules have not been altered substantially for at least half a century; and it possesses a remarkably accurate and faithfully kept set of statistical data through which hundreds of thousands of games have been recorded. There are some 40 symbols and abbreviations used in recording the box score of a game, for example. These data are not confined to the professional leagues; countless collegiate, interscholastic, and sandlot leagues maintain their own records.

It is this set of unique characteristics, as contrasted with other team sports, that makes the strategy of the game subject to analysis through the application of probability theory. When a coach quotes the percentages on which a particular maneuver is based he is, in effect, describing the chance of a successful event occurring. This chance is calculated by the simple technique of dividing the total number of times the event has occurred into the total number of successes. A batting average (hits/at bats) thus is a probability. Multiplying this answer by 100 yields a percentage. Thus a player who is hitting 0.300, for example, has hit successfully 30 percent of the time, or a team with a won-lost record of 0.540 has won 54 percent of its games Similar but more complex calculations can be made to describe the chance of successfully sacrificing a runner with none, or one, out, the chance of a pitcher throwing nine innings, the chance of stealing a base, and so forth.

The reader can now identify other aspects of the game for which probabilities can be derived. It is important to note that a probability, or percentage, is more likely to be accurate when calculated from a large number of repetitions. The instability of early season batting averages illustrates this point. When interpreting a probability, note that it does not infer that a 0.333 hitter will hit every third time at bat, but rather that over a large number of at-bats the hitter can be expected to hit safely about 33 percent of the time. Note also that each separate time at bat is independent of any other Within the past few years the probabilities of most of the game's situations have been calculated. The majority of these studies have been confined to the major leagues; nevertheless, many of the findings can be generalized to other levels of performance.

A most exhaustive, thorough, and sophisticated analysis has been recently completed by Earnshaw Cook, and is the subject of his book *Percentage Baseball* (6). This book is *must* reading for all coaches, fans, and students of the game. Mr. Cook has derived conclusions about the strategy of the game that are startling, and which are in direct contrast to the way in which the game is played today. He bases his conclusions on the analysis of thousands of major league games, and reports hard statistical evidence for his findings. In capsule form some of Mr. Cook's conclusions are:

1. Always *start* a relief pitcher, and remove him for a pinch hitter on his *first* turn at bat This is as long as he is usually in the game anyhow. Then substitute a starting pitcher, allowing him to bat once only if working well. Unless the team is comfortably ahead he should not bat a second time (this would be after five innings; the probability of being knocked out of the box is 2 to 1 against him). The same general reasoning applies for the subsequent pitchers. Mr. Cook demonstrates that by inserting pinch hitters for the pitcher a team can score 113 more runs per season.

2. The sacrifice bunt actually and significantly decreases the chances for scoring. By eliminating it, except for weakly hitting pitchers, a team can score 63 more runs per season. The stolen base, however, considerably enhances the probability of scoring

3. *The hit and run* play is the most powerful and the least exploited strategy in baseball.

4. Arrange the batting order so that the eight most productive players appear in descending sequence of ability (a gain of 73 runs scored per season).

It is obvious that Mr. Cook is a keen student of baseball and that his opinions are not to be taken lightly. The reader may recall that Bobby Bragan, ex-manager of the Pittsburgh Pirates and the Milwaukee Braves, had the courage to defy tradition by selecting his strongest batsman to lead off and placed the remainder in descending order. This arrangement insured that the stronger batters would come to the plate more times per season. Mr. Bragan tried this approach for the last 40 games of the 1956 season, however the limited number of games was too small to support any conclusion. The Pirates won 14 and lost 26 and were 0.350 for the 40 games immediately preceding the experiment, and were 0.400, winning 16 and losing 24 for the 40 games using the experimental lineup.

It is interesting to note that other analysts, working independently, have arrived at conclusions generally similar to some of Mr Cook's findings. A sophisticated statistical analysis by Lindsey (8) concludes that the strategy of sacrificing with a runner only on first base does not appear to be a wise one. The squeeze play is good strategy if one run is badly needed late in the game. These conclusions are in substantive agreement with Cook, except that Cook has deferred any statistical conclusions about the relative merits of the squeeze play. Lindsey also points out that the slugging average, which measures the average number of bases gained by the batter by his own hitting, is also quite a good indication of the contribution that the batter's performance would have made toward the expected number of runs scored by his team.

Lindsey (10) also reports data gathered during the 1951 and 1952 seasons from games played in the National, American, and International Leagues which related directly to game strategy Several of his conclusions substantiate what has been common practice by many major league managers. He shows that left-handed hitters hitting against right-handed pitching, and right-handed hitters hitting against left-handed pitching, do have a slight advantage over those batting left against left or right against right. Since these theories have been constantly debated the results are presented for inspection in Table 3.

Note that over 6,000 times at bat of the same batting "handedness" produced a total batting average of 0.231, as compared to 0.263 for over 6,000 times at bat of the opposite handedness, a difference of 0.032, or about three percent. This difference is statistically significant It is also interesting to note that a right-handed batter does about as well against a right-handed pitcher as a left-handed batter does against a left-handed pitcher, with a similar comparison for the case of "opposite."

Other data reported by Lindsey support the contention of many coaches about certain defensive strategies. For example, it is shown that if the bases are full with none out, and the fielding team allows one run to score while executing

TABLE 3.

Batter		Pitcher	AB	H	Average
R		R	5,197	1,201	0.231
L		L	1,164	270	0.232
	Same		6,361	1,471	0.231
L		R	4,002	1,055	0.264
R		L	2,245	590	0.263
	Opposite		6,247	1,648	
	Overall		12,608	3,116	0.247

Adapted from Lindsey (10).

a double play, they have reduced the expected number of runs and in most circumstances greatly increased their chances of winning Other interesting observations indicate that, if the bases are full with none out, the batting team has an expectation of scoring 2.3 runs before the inning is ended, and has a probability of about 25 percent of scoring more than three. With the bases full and two out, however, the expectation is only 0.9 runs, and the probability of scoring more than three is only about 10 percent.

Other studies (7, 9) agree that slugging percentage seems a better evaluation of a hitter's effectiveness than a batting average. Power hitting as measured by home runs and possible triples has much less to do with winning than has the steady hitting of singles.

Research on 7,332 games in the major leagues from 1932-1937 disclosed that the home team won about 55 percent of its games in both leagues. This was true regardless of whether a team was in the first or second division in the standings (3).

Studies done on the statistics of World Series competition are very interesting. There is universal agreement that the outcomes of games in the series are independent, and that the probability of winning any single game is constant throughout the series. In other words, a coin toss is as good a predictor for any single game as any other method. Since the pennant winners in each major league are so evenly matched, it is concluded that the actual statistical distribution of won-and-lost combinations approaches that of pure chance (6, 11).

Summary

The last five years have produced the first sophisticated statistical calculations of the percentages involved in the various situations in a baseball game.

The author does not present the research reviewed here as gospel, nor is it suggested that baseball abruptly turn about and incorporate the findings of the research reported. It is a fact, however, that baseball has historically regarded changes in strategy suggested by statistical research with polite indifference, and perhaps may be overlooking recommendations that could abruptly and dramatically improve performance. At least the suggestions posed by these researchers are based on statistical fact, *not* on the folklore of the game, and present refreshing and intelligent analyses that have not heretofore been forthcoming.

The research reviewed also suggests another provocative question. Can these findings be generalized to college, high school, and boys baseball leagues where the number of games played is fewer in number than the major leagues? Would these probabilities hold true in a short season? The answer lies in the fact that over a period of a number of seasons these probabilities would undoubtedly approximate the results reported, and perhaps a consistent philosophy will pay dividends even though the results may not be immediately apparent There surely is room for experimentation at these levels with players of lesser ability; there seems no apparent reason to ape the major leagues in everything they do. Certain modifications of the findings to better fit the level of ability could be incorporated into a coach's strategy. Not letting pitchers come to bat, for example, could be ignored, because at the early stages of development the pitcher is usually the best athlete and hitter. Certainly the modification of the batting order, increased emphasis on stealing and taking the extra base, and on the hit and run could lead to more successful seasons.

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5. A BASEBALL POTPOURRI

Baseball literature provides a good deal of research in a variety of areas, including baserunning, throwing, reaction and movement times of players, sociological aspects of the game, research on the ball itself, and other interesting and related topics that happened to strike the researchers' fancy. There is not a sufficient number of studies in these areas from which to establish a current state of the art; nevertheless interesting topics are explored and serve to illustrate the variety of subjects other than batting, pitching, and strategy which have been investigated. These areas will be briefly reviewed in this chapter.

Baserunning

Research germane to the specific skill of baserunning is scarce. Most findings have been confined to analyzing the best technique to use in rounding first base (thus generalizing to circling the bases). It is very difficult to generalize from these findings to the many aspects of running the bases; some conclusions, however, may be identified.

It is interesting to note that left-handed batters do, on the average, have an advantage when running to first base, although the advantage is slight. This slight edge is due entirely to the shorter distance run, rather than the running speed. Right-handed batters run approximately 92 feet, while the left-handed batters run only 88 feet to first base. The average speed for left-handed batters has been reported at 21.27 feet per second as opposed to 21.20 feet per second for right-handed batters (12). The important and interesting fact is that the right-handed batter actually makes better time running to first base, but he is running a greater distance. The better time (for the distance covered) results from the momentum of the right-handed batter's swing, which literally starts him in motion towards first base, whereas the left-handed batter's momentum throws him to the right of the baseline and results in a delay in getting his body back into line before starting to run to first base.

The best method of rounding first base has been examined by several investigators. Various techniques studied have included "rounding out" at 60 feet and touching first base with the left foot; also the same with the right foot, running directly to first and turning sharply at the base, and touching first base and, with both feet facing second, making a sharp 90° turn (7). It appears that the best method of running from home to first base is to run just outside the foul line and straight at the base until the runner can conveniently turn and approach the bag in the best position to continue to second in as straight a line as possible. Obviously, the more the deviation from a straight line from first to second, the greater the increase in running time, due to the greater distance run. Therefore, to overcome centrifugal force the runner should lean inward as much as possible when making his turn. Apparently it makes little difference which foot first contacts the base; the important thing is not to break stride and to attempt to contact the inside corner of the base.

When trying to beat out a ground ball to the infield the practice of leaping to first base the last stride or so, or of sliding into the base, should be avoided. When the runner leaps higher into the air than he would in his normal running stride his forward speed is retarded and it will take him a split second longer to reach the base (29) A similar disadvantage occurs when sliding, as the sliding action of the body along the ground, as well as the act of lowering the body into the slide, slows down the speed. The only excuse for sliding into first base is to avoid a tag. Note that these same principles hold true when running to second or third, except that it is frequently necessary to sacrifice some speed by sliding, not only to avoid a tag, but to stop at the base in order not to overrun it.

Basestealing techniques have also been studied. The single most important technique in stealing a base is to be in motion with the pitch, in other words, "get a good jump." It is more important to attempt to walk off the base to obtain a running start than it is to have a relatively large lead and start from a standstill. The relative merits of the cross-over step or the lead-out step start are unimportant when compared with the art of getting a walking start.

Throwing

Studies related to throwing (other than pitching) have shed little light on these skills that has not been previously identified through the application of good mechanical principles (13, 31, 34, 36). Where velocity and distance are the goals the overhand throw is generally best. It should be noted, however, that the overhand throw, especially in the infield, is not always the best method to use.

While it generally results in greater velocity and accuracy, a fielder is not always in the most advantageous position to make this type of throw, and it takes more time to get the throw off. The sidearm and underarm throws enable the infielder to get the throw off much more quickly, and the quickness of release is often more important than distance in infield play. An outfielder attempting to throw out a runner who is advancing a base should use the overhand throw, and, if no cut-off man is needed, should throw the ball on the fly to the base with as little arc as possible, rather than bouncing the ball to the base on a hop. The retarding effects of friction on the speed of the ball are obvious.

A number of investigators have reported gains in both speed and accuracy following an overload warm-up; that is, throwing a weighted ball prior to game activity. Most of this research was conducted on performers who possessed a high level of skill. The research evidence is conflicting; however, there are some data which disclose no improvement in either speed or accuracy following an overload warm-up. It is difficult to reach any conclusion in this area; the question of using an overload warm-up or training with the same size and weight object that is used in competition cannot be conclusively answered at this time.

Modification of Equipment

One frequently hears the argument that baseball equipment (bats, gloves, etc.) should be modified at the lower age levels, but that if youngsters are really to learn the game they should play with the standard size ball. Some of these old tales die hard deaths; let us hope that this one can be put to rest forever. There is a great deal of evidence which discloses that the modification of the size of the ball to adapt it to the abilities of younger players results in great improvements in throwing accuracy and distance. The beneficial effect of using a smaller ball is also evident when one teaches the basic skills of throwing and catching to youngsters with limited strength.

Reaction and Movement Time

The importance of reaction and movement time to batting have been discussed in Chapter One. The fielding aspects of the game, however, also obviously require quick reactions and movements, and, naturally, one might pose the question, "Do baseball players react and move more quickly than other athletes?" The research findings are in general agreement that compared to other athletes, such as football backs, gymnasts, basketball players, and football linemen, there seems to be no evidence of superiority.

Personality Traits

Data which are specific to the personality traits of baseball players disclose some inconsistencies and conflicts. Most of these differences can be attributed to the instruments utilized to assess personality and the different populations studied; that is, college varsity and freshman baseball players, minor leaguers, and major league performers. Where baseball players have been compared with nonathletes differences in personality traits have been reported in many cases.

When major league players have been compared with minor leaguers there is some indication that the major leaguer exhibits a stronger drive toward his objective by exercising self-discipline and initiative, and is better able to get along with other people than players who have remained in the minor leagues. These data were reported in 1954; they may not be representative of modern players.

Comparisons with varsity and freshman tennis players at a Midwestern university have indicated that varsity and freshman baseball players disclosed lower profiles in achievement, ability to analyze others, leadership, and inferiority. When the baseball players were classified according to ability no differences in personality traits among the better or poorer players were noted.

It seems apparent that there is little evidence available from which to draw any definite conclusions about the personality traits of baseball players in general, and that the area of psychological assessment appears to present an interesting area for the accumulation of further information.

Physical Demands of the Game

The physical demands and requirements of the game pose some unique questions when compared with other team sports. What is the physical condition of baseball players compared to other athletes? What, if any, differences are there between positions? What type of physical condition should a player (other than pitcher or catcher) be in when he is commonly required to supply a maximum effort only once or twice a game? There are little, if any, data available from which answers to these questions can be formulated; several studies, however, yield some indication of the extremely great variability in energy output required by different positions.

One unique study attempted a time and motion analysis of intercollegiate baseball players. A recapitulation of the average performance of an infielder revealed that in the entire game he traveled a distance of 0.83 miles, of which 0.49 of a mile was traversed at high speed and 0.34 of a mile was traversed at low speed. Of this total distance, about 51 percent was traveled going to and from his position. This player made 24 warm-up throws, five throws in actual play, and 16 throws after putouts, for a total of 45 throws during the entire game. He also made 2 assists, 5 putouts, and 33 acute turns while traveling at high speed. At bat he swung at the ball six times, hit it five times, and missed it once. The game was played in the Big Ten Conference and lasted about two hours and ten minutes (11). It is quite evident that this does not represent a physically exhausting afternoon's performance. This same conclusion, however, does not necessarily apply to the pitcher. Data obtained by telemetering the heart rate of a pitcher during an intercollegiate freshman game have shown that a combination of physical and emotional stress caused a pitcher's heart rate to exceed 180 beats per minute several times during a nine-inning game, and that the heart rate did not drop below 100 during the two hours of competition. A pregame rate of 174 beats per minute and a peak rate of 193 beats per minute during the game were also reported (32). These heart rates are comparable to the energy demands of paddleball, squash, and tennis

Sociological Aspects of Baseball

Most of the published research related to the sociological aspects of the game is pre-1960. The findings represent a patchwork of fragmented pieces of information that are difficult to make into any pattern, and may not be directly relevant to the game today. Nevertheless, the findings are summarized below.

Research findings published between 1938 and 1940 indicated that the most proficient years for a player were from 28 to 29 years of age. California and Arizona contributed most of the players from the Southern states and Pennsylvania and Ohio the most from the North.

Follow-up studies of major league players in the early 1950s reported that the jobs held most frequently by retired ball players were in the professional and technical classifications (83 percent). The occupational distribution of the players studied did not resemble closely the occupational distribution of male workers as reported in the 1950 census.

An excellent sociological and economic analysis of baseball players' occupations was written by Gregory (14) in 1956. It will not be reviewed here but is recommended to those interested in the game as played in the early 1950s.

Antitrust Laws

The biggest legal headache that has confronted baseball since its popularity and commercialism have grown has been the question, "Does baseball come within the scope of the federal antitrust laws?" In 1922 the Supreme Court decided that it did not. Justice Holmes ruled that the game did not fall within interstate commerce since traveling was a "mere incident, not the essential thing," and that "personal effort, not related to production is not a subject of commerce." This ruling was challenged in 1952 by law suits charging violations of the antitrust laws The target of these suits was the controversial "reserve clause," which gives the club originally signing the player exclusive rights to his services, and which also gives the same club the power to trade or sell the player to any other club without the player's consent if it so desires. Most of these suits were adjudicated. Also in 1951, a bill designed to give baseball and all other professional sports enterprises carte blanche immunity from antitrust laws was tabled by a House subcommittee which, interestingly enough, concluded that "such a broad exemption could not be granted without substantially repealing the antitrust laws." No legislation was recommended at that time. Recently a suit by Curtis Flood, a St. Louis Cardinal outfielder, challenging the reserve clause, also lost, but is being appealed. This was the first challenge since 1952.

The Supreme Court has ruled that football and boxing specifically are subject to antitrust laws. Show business also comes under this umbrella Baseball alone still remains outside of this legislation under the tent of the 1922 and 1952 decisions. Could it be that a majority of the justices were baseball fans?

Prediction of Baseball Ability

As intimated in Chapter One, there has been very little done in predicting baseball ability from objective tests. The Sargent Jump has been generally selected as the best single measure for selecting baseball talent, but this generalization should be viewed with caution, because athletes in general will score well on this particular item. Objective tests which could truly evaluate baseball ability would be welcomed by college and high school coaches as well as professionals. The subjective opinion of experts still is the primary criterion for prediction.

The Ball

The argument as to whether the ball is livelier than it used to be has raged for years. Attempts to make a thorough study of "the excessively heavy batting of the last few years" were made as early as 1925. The "rabbit baseball" controversy is one of the oldest in sports. Recent tests made by independent research laboratories indicate that the ball *is* becoming livelier. Spaulding and Brothers, who manufacture all official baseballs, disagree, maintaining steadfastly that they have been making the same ball for years. The concensus of the scientific findings indicates that while the ball has essentially remained the same, the yarns used in its manufacture and the tightness of the windings have changed somewhat. More important, the coefficient of restitution has not changed significantly when the ball is hit at high bat speeds, but at lower bat speeds the balls are much bouncier and more lively. Perhaps for hitters such as Frank Howard the ball is not much livelier, but for lighter, less powerful players it might respond better. Other variables also are involved. Management is paying for home runs, as illustrated by

Ralph Kiner's classic remark, "The Cadillacs are at the end of the bat." Players today are bigger and stronger than ever and they are using shorter, lighter bats. Baseballs are fresher at any moment of the game, some four dozen balls are used in each major league game. A fresh ball is more resilient than one that has been batted a number of times. One might conclude that the argument will rage on anew, and unresolved.

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6. THE EXTRA INNING

This synthesis of research findings has revealed that the majority of published research has been concentrated in the areas of batting and pitching mechanics, which have been firmly established. Somewhat disappointing, with a few notable exceptions, is the lack of concentrated research efforts in other aspects of the game, such as those discussed in Chapter Four. There appear to be fruitful areas for additional work related to the economic, legal, and sociological aspects of the game, game strategy, movement and reaction time of fielders, the effects of synthetic surfaces, the energy cost of different positions, and the development of new and better equipment. This list is by no means all-inclusive.

Physical educators have been historically remiss in initiating the research and development of new types of equipment. Perhaps the previous undergraduate and graduate training of specialists in the field has been so closely allied to the teaching and coaching field that most research has been predominantly of an applied nature Cost may eventually demand the researching of new and promising ideas, such as the development of better safety head gear, bats made of aluminum or other synthetics, or lighter and better protective equipment.

The effect of artificial turf on sliding, on the spin, bounce, and velocity of batted balls is also challenging. It is interesting to note that no major league baseball stadium has a completely artificially turfed infield the infield dirt still remains as the last bastion of baseball's historical resistance to change. Cincinnati's new Riverfront Stadium represents at least a compromise; only the area immediately surrounding the bases is dirt.

The ball itself represents a challenging area of research. Most readers will recall that all baseballs are still hand-stitched; a machine which can automatically perform this function is yet to be developed. While the major leagues may cling to the belief that (at least for publication) the composition of the ball must not change, the technology exists to devise a ball with equal resiliency, shape, and feel, that cannot be classified, as is Kleenex, as a disposable item. The major leagues may still be able to afford the use of approximately four dozen balls per game. It is extremely doubtful that other coaches and devotees of the game would not welcome (and, incidentally, pay for) a cheaper and a longer lasting ball

It is also interesting to note that scholarly, sophisticated, and penetrating computer analyses investigating the *real* percentages of the game have come from people who can be classified as outside the field of physical education and athletics. The single most objective, scholarly, provocative, and inclusive investigation into the strategy of the game was done by an open hearth engineer as a hobby. Systems research analysts and statisticians have contributed most of the remainder, presumably in their idle time. The lack of consideration and discussion (not to mention application), of these data by coaches is somewhat discouraging. Perhaps one's feelings in the matter can be assuaged by the hopeful assumption that this review will help serve to cross the alleged bridge between researcher and practitioner. One might at least assume that baseball strategy could be improved, for example, to produce better results for teams endowed with lesser talents, rather than accepting the fact that "they just don't have the ability." It may just be possible that the game plans utilized by the Yankees of the Casey Stengel era, or this year's Baltimore and Cincinnati teams, are more the result of talent than strategy. However, in college, high school, or in boys baseball, strategy is relatively unimportant only if one has overwhelming talent (the exception, rather than the rule). It is easy to ape the successful teams in the major leagues, and thus encourage the folklore which has perpetuated itself. This syndrome has been manifestly evident in the "how-we-do-it union" of professional baseball players, and coaches who have played the game.

Baseball is irretrievably a part of the sociology of the American people. Perhaps, as some sportswriters and team owners have suggested, it may be best not to radically disturb the underlying conservatism, legends, or nostalgia of the game's history. This philosophy, incidentally, has not been followed in other sports, notably basketball and football The conservatives may have a point. But most of the researchers quoted in this review, would, I think, disagree.